The Non-point Source Pollution Effects of Pesticides Based on the Survey of 340 Farmers in Chongqing City

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Abstract Using the survey data on 340 farmers in Chongqing City, this paper performs an empirical analysis of the factors influencing the non-point source pollution of pesticides. The results show that the older householders will apply more pesticides, which may be due to the weak physical strength and weak ability to accept the concept of advanced cultivation; the householders with high level of education will choose to use less pesticides; the pesticide application rate is negatively correlated with whether farmers have participated in agricultural technology training, that is, the farmers having participated in agricultural technology training have stronger ability to scientifically apply pesticides, and in-depth understanding of advanced agricultural production technology and positive and negative effects of pesticides, so they often choose to reduce the application rate of pesticide; the cognitive factor on the role of pesticides in better promoting the growth of crops is significant, which requires the government and relevant departments to carry out concrete publicity of effectiveness and negative impact of different pesticides during the popularization of agricultural science knowledge, to prompt farmers to have a systematic and in-depth understanding of the agricultural non-point source pollution caused by pesticides.

Key words Farmers, Pesticides, Non-point source pollution effects

1 Introduction

Modern agricultural production is inseparable from the use of pesticides which have made great contribution to Chinese social and economic development. But at the same time, pesticides are also the toxic chemicals imposed by human on the environment. In a country producing and consuming a lot of pesticides, the pesticide pollution is inevitable, and it is necessary for people to take appropriate measures to combat pesticide pollution and minimize the losses while affirming the positive role of pesticides. China is one of the countries first discovering and using pesticides and the pesticide consumption is highest in the world, but the management of pesticides started late. In 1997, China promulgated *Pesticide Management Regulations*, indicating that China entered the era of managing pesticides in accordance with laws. In the long-term use of pesticides, it has caused tremendous pollution and damage to the environment. At the same time, the pesticide pollution causes a serious impact on human body. First, during the production, transportation, storage and use of pesticides, humans are directly poisoned; second, through the food chain, humans are indirectly poisoned. With the global economic integration and development needs of agricultural products in the new phase, Chongqing City has been one of China's important agricultural commodity production bases and pollution-free agricultural products and green food have make great strides in Chongqing. However, due to the humid climate and short frost-free period, vegetable can be cultivated all year round and vegetable pests occur frequently, so the pesticide residues on vegetables caused by unreasonable application of pesticides can not be ignored. For these reasons, with the survey data on 340 farmers in Chongqing City, we try to study the non-point source pollution effects of pesticides and put forth the relevant recommendations in order to provide a reference for understanding the current situation of pesticide pollution in China.

2 Data sources and statistical analysis

2.1 Data sources Chongqing has a long history of agricultural development, and there is a wide use of pesticides. The non-point source pollution of pesticides appeared early and it is typical, so Chongqing City is selected as the study area. In this paper, using the cross-sectional data, we carry out a questionnaire and interview survey of 340 farmers in Chongqing City.

2.2 Statistical analysis This survey covers type of pesticide, whether to consider their own consumption during pesticide application, agricultural material sales points, agricultural material prices evaluation and cognition of pesticide application.

2.2.1 Type of pesticide. During the survey, it is found that the proportion of using a large amount of green pesticides is 28.24% and the proportion of using a small amount of green pesticides is 45.29%. It is worth noting that the farmers who use a small amount of highly toxic pesticides or use no highly toxic pesticides account for 94.41%, and the farmers who use green pesticides account for 73.53%, but the proportion of considerable use of green pesticides is low, indicating that the green pesticides promotion has achieved some success, and farmers begin to try applying green pesticides, but most farmers hold a wait-and-see attitude.

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Table 1 Pesticide type selection

	Green pesticides			Highly toxic pesticides		
	A large amount of application	A small amount of application	No application	A large amount of application	A small amount of application	No application
Frequency	96	154	90	19	180	141
Proportion	28.24%	45.29%	26.47%	5.59%	52.94%	41.47%

2.2.2 Whether to consider farmers' own consumption during pesticide application, agricultural material sales points and price evaluation. When all agricultural products are for their own consumption, most farmers prefer to use more green pesticides and less chemical pesticides. The proportion reaches 40.29%, indicating that more and more farmers realize the hazards of pesticide application to food safety. In Chongqing, there is at least one agricultural material sales point in more than half of the villages. For the evaluation results of agricultural material prices, only one tenth of the farmers think it inexpensive and are fully able to withstand agricultural material prices and more than 40% of farmers think the agricultural material in recent years is high. This may be related to the fact that there is only one sales point in the village for the majority of farmers, lacking effective market competition mechanisms of agricultural materials.

Table 2 Whether to consider their own consumption during pesticide application, agricultural material sales points and price evaluation

	Whether to consider their own consumption during pesticide application			Agricultural material sales points			Agricultural material price evaluation		
	No, treating alike the agricultural products for their own consumption and sale	Yes, more green pesticides for the agricultural products for their own consumption	No comparison	1	2	3 or more	Inexpensive	Basically accepting	Very expensive
Frequency	90	137	113	190	107	42	37	164	139
Proportion	26.47%	40.29%	33.24%	56.05%	31.56%	12.39%	10.88%	48.24%	40.88%

2.2.3 Cognition of pesticide application. Survey results show that although the pesticide application will contaminate agricultural production environment and affect the quality of agricultural products, the vast majority of farmers do not think that the pesticide has been applied in excess, and 38.82% of farmers believe that the pesticide has been excessively applied. Meanwhile, the vast majority of farmers have a more objective understanding of application effect of pesticides, and 72.94% of farmers believe that the application of pesticides is not necessarily conducive to crop growth. It should be noted that 7.06% of farmers do not know whether the pesticide application can promote the growth of crops in Chongqing City, which shows that the knowledge of agricultural production needs to be further popularized.

Table 3 Farmers' cognition of pesticide application rate and effect

	Cognition of pesticide application rate			Cognition of pesticide application effect		
	Excessive	Without excess	Unclear	Effective	Ineffective	Unclear
Frequency	132	191	17	68	248	24
Proportion	38.82%	56.18%	5.00%	20.00%	72.94%	7.06%

In terms of farmers' cognition of pesticide hazards, the vast majority of farmers believe that the application of pesticides will bring pesticide pollution, and affect agricultural production and food quality. More than 91% of the farmers think pesticides will have an impact on soil, air and water quality, and about 95% of farmers believe that pesticides can affect the quality of agricultural products.

Table 4 Farmers' cognition of pesticide hazards

	Quality of soil, air and water body			Quality of agricultural products		
	Serious impact	Not serious impact	No impact	Serious impact	Not serious impact	No impact
Frequency	89	221	30	96	225	19
Proportion	26.18%	65.00%	8.82%	28.24%	66.18%	5.59%

3 Model estimates and analysis of the results

3.1 Modeling Application of pesticides by farmers is affected by multitudinous factors such as basic characteristics of rural householders, family and production characteristics, commodity trading characteristics, scientific pesticide applying ability characteristics, farmers' cognition of pesticide residues, and local pesticide purchase place and price. Therefore, the model of factors in-

fluencing farmers' pesticide application rate is built as follows:

$$SP = f(BC, FC, Trade, SC, RE, PP) + \varepsilon$$

where the dependent variable *SP* is farmers' pesticide application rate; *BC* represents basic characteristics of rural householders; *FC* represents farmers' family and production characteristics; *Trade* represents commodity trading characteristics; *SC* represents farmers' scientific pesticide applying ability characteristics; *RE* is farmers' cognition of pesticide residues; *PP* is local pesticide purchase place and price; ε is random disturbance term.

3.2 Variable selection (i) Basic characteristics of rural householders (*BC*), including the age and educational level of householders. On the one hand, younger farmers may be more concerned about crop yields under the stress of livelihood, thereby increasing the amount of pesticide application. On the other hand, older farmers are generally more dependent on experience in the agricultural production activities, and reluctant to accept new ideas about pesticide application; they are often relatively weak and thus increase the application rate. It is generally believed that the higher the educational level of farmers, the stronger the ability to accept new ideas and new technologies, the stronger the willingness to scientifically apply pesticide, and the more likely they are to apply the right amount of pesticides. (ii) Farmers' family and production characteristics (*FC*), including annual family income, gender of main labor, and the proportion of population engaged in agricultural production and total household population. Annual family income has an uncertain impact on the pesticide application rate. The family with female labor as the main labor may use more pesticides to compensate for constraints of physical work capacity. In addition, the family with a large proportion of agricultural population may choose to use the pesticides which can increase crop yields. (iii) Commodity trading characteristics (*Trade*). The crops with low commodity rate are mostly consumed by farmers themselves and they may apply less pesticides. However, the farmers with high commodity rate are engaged in large-scale agricultural production, and they often have stronger awareness of costs and benefits and ability to accept advanced technologies, leading to reduction in the amount of pesticide application. Therefore, the commodity rate of crops has an uncertain impact on pesticide application rate. (iv) Farmers' scientific pesticide applying ability characteristics (*SC*), including whether the farmers can understand the instruction for use, and whether the farmers attend the agricultural technology training. It is assumed that the participation in agricultural technology training will have a negative effect on the pesticide application rate. (v) Farmers' awareness of pesticide residues (*RE*), including farmers' awareness of whether the excessive use of pesticides will affect the quality of soil, air and water and the quality of agricultural products, and whether pesticides can promote crop production. (vi) Pesticide purchase place and price (*PP*), including the number of agricultural material sales points in farmer's village and farmers' ability to bear the pesticide price. If there are many agricultural material sales points in farmer's village, it is likely to increase the likelihood of farmers' purchase of pesticides. When farmers believe that the current price of pesticides is not high, they are more likely to purchase and use pesticides.

Table 5 The main study variables and their definition

Variable name	Variable definition
Variable to be explained:	
Farmers' pesticide application rate (*SP*)	Frequency of farmers' pesticide application
Explanatory variables:	
(i) Basic characteristics of rural householders (*BC*)	
Age	Young adults = 1, middle-aged and old adults = 0
Educational level	Primary school = 1, junior high school = 2, senior high school = 3
(ii) Farmers' family and production characteristics (*FC*)	
Annual family income (FC_1)	The total annual family income
Gender of main labor (FC_2)	Male (1); female (0)
Proportion of population engaged in agricultural production and total household population (FC_3)	Population engaged in agricultural production/total household population
(iii) Commodity trading characteristics (*Trade*)	Agricultural products sold/total agricultural production
(iv) Scientific pesticide applying ability characteristics (*SC*)	
Whether the farmers can understand the instruction for use (SC_1)	Yes (1); no (0)
Whether the farmers attend the agricultural technology training (SC_2)	Yes (1); no (0)
(v) Farmers' awareness of pesticide residues (*RE*)	Understand (1); do not understand (0)
Whether the excessive use of pesticides will affect the quality of soil, air and water (RE_1)	Yes (1); no (0)
Whether the excessive use of pesticides will affect the quality of agricultural products (RE_2)	Yes (1); no (0)
Whether pesticides can promote crop production (RE_3)	Yes (1); no (0)
(vi) Pesticide purchase place and price (*PP*)	
The number of agricultural material sales points in farmer's village (PP_1)	The number of agricultural material sales points Yes (1); no (0)
Whether farmers can bear the pesticide price (PP_2)	

3.3 Regression results and analysis From Table 6, the regression results show that age and educational level of rural house-

holders, whether the farmers attend the agricultural technology training (SC_2) and whether pesticides can promote crop production (RE_3) pass the significance test, while other variables do not pass the significance test, possibly due to small sample size and inaccurate regression results, but we can roughly judge the positive and negative effects of these factors on pesticide application rate from the sign of regression coefficient. In the variables passing the significance test, the family with older householder will apply more pesticides, because their physical labor is limited and they are more likely to apply more pesticides to make up for the lack of the ability to work; the householders with high educational level will choose to use less pesticides, which may be related to the social concept of the region. The pesticide application rate is negatively correlated with whether the farmers attend the agricultural technology training (SC_2), indicating that the farmers who have participated in agricultural technology training will have stronger scientific pesticide application ability. In addition, the coefficient of RE_3 is significant, and farmers will use more pesticides in order to seek higher crop yields and more agricultural production profits if pesticide application can promote crop production.

Table 6 Regression results

Variable	Constant	*Age*	*Educational level*	FC_1	FC_2	FC_3	*Trade*
Coefficient	2.292***	0.565**	−0.785***	−4.06E−06	0.159	0.309	−0.083
	(−5.1)	−2.5	(−9.02)	(−1)	(−0.87)	(−1.08)	(−0.58)
Variable	SC_1	SC_2	RE_1	RE_2	RE_3	PP_1	PP_2
Coefficient	0.371	−0.354***	−0.266	0.191	0.289**	0.101	0.023
	(−1.54)	(−2.79)	(−1.03)	(−0.64)	(−2.08)	(−1.2)	(−0.19)
Number of samples	340		*Adj* R^2	0.25		*F* value	9.63

Note: *, **, *** indicate that it is significant at the level 10%, 5% and 1%, respectively; what within the brackets denote *T* value.

4 Conclusions and recommendations

4.1 Conclusions Using the survey data on 340 farmers in Chongqing City, this paper performs an empirical analysis of the factors influencing the non-point source pollution of pesticides. The results show that the older householders will apply more pesticides, which may be due to the weak physical strength and weak ability to accept the concept of advanced cultivation; the householders with high level of education will choose to use less pesticides; the pesticide application rate is negatively correlated with whether farmers have participated in agricultural technology training, that is, the farmers having participated in agricultural technology training have stronger ability to scientifically apply pesticides, and in-depth understanding of advanced agricultural production technology and positive and negative effects of pesticides, so they often choose to reduce the application rate of pesticide; the cognitive factor on the role of pesticides in better promoting the growth of crops is significant, which requires the government and relevant departments to carry out concrete publicity of effectiveness and negative impact of different pesticides during the popularization of agricultural science knowledge, to prompt farmers to have a systematic and in-depth understanding of the agricultural non-point source pollution caused by pesticides.

4.2 Recommendations (i) In terms of technical measures, we can enhance the pests and diseases forecasting and resistance monitoring, adjust the pesticide structure, research and develop low toxicity and efficient pesticide s and biological pesticides, and promote new biological control technologies and products. (ii) From the management measures for pesticide pollution prevention, we can strengthen the supervision and management of pesticides, strengthen technical advice for farmers' pesticide use, enhance publicity to raise people's environmental awareness and self-protection awareness, strengthen environmental management of pesticides, systematically carry out the environmental management and environmental monitoring after pesticide use, establish and improve pesticide environmental management system, and strengthen environmental management of pesticides. (iii) From the measures for development of biological pesticides, we can implement demonstration projects to promote the use of bio-pesticides and conduct biological control to promote sustainable development of agriculture.

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(To page 67)

7.3 Encouraging developing urban areas and industries using Gobi deserts in accordance with actual situations of western areas, to realize the objectives of increase in construction land but decrease in farmland area Gobi deserts are mainly distributed in Xinjiang, Qinghai, Gansu, Inner Mongolia, and northeast of Tibet. According to preliminary statistics, Gobi deserts account for 30% of the total land area of Xinjiang Uygur Autonomous Region; Gobi deserts account for 29% of total land area of Gansu Province; in Qinghai, Inner Mongolia, and Tibet, the proportion is 13 – 15%. Gobi deserts are buffer areas of oasis and deserts. In many areas of Gobi deserts, underground water is plentiful and thus it is suitable for developing as construction land. Using Gobi deserts to develop urban areas and industries does not occupy farmland and other agricultural land. Therefore, it guarantees priority development of agriculture and protection of ecological environment. Also, developing satellite towns in accordance with characteristics of northwestern areas avoids developing urban areas like making big cakes. It not only takes full advantages of land resources, increases land use efficiency, and prevents expansion of deserts and shrinkage of oasis through building ecological industrial parks or towns in such buffer areas. Therefore, it is recommended to formulate preferential policies to encourage developing towns and industries using Gobi deserts. For example, these areas can provide preferential policies in taxation for enterprises in investing in development of Gobi deserts without occupying the annual target of new construction land.

8 Establishing land circulation access system to ensure unchanged land use purpose and high efficient use

In the process of urbanization, it is required to keep in step with industrialization, informationization, urbanization, and agricultural modernization. Agricultural modernization is the last barrier. Without agricultural modernization, there will be no urbanization in real sense. Agricultural modernization is marked by large-scale, mechanization, scientific, intensive, industrialized, commercialized, and socialized characteristics. Evidently, in current household contract responsibility system, the precondition for developing modern agriculture is circulation and concentration of land[6]. Land contractual management right enjoyed by rural households can be circulated, participating in shares or returning to their communities. They can also go to cities to work or be employed by land inflow people to become agricultural workers. This not only centralizes separate land, lays foundation for development of modern agriculture, but also liberates much labor to support urbanization and industrialization development. Nevertheless, many local areas still take administrative means to force farmers to circulate their land. Some enterprises hoard land in the name of land circulation. Some enterprises even do not have the qualification of operating agriculture. As a result, due to improper management, land circulated becomes idle or waste land. Some enterprises just abandon such land, and those enterprises have management capacity basically adopt non-grain operating model. These problems will ultimately be detrimental to agriculture, farmers and rural areas. Therefore, it is urgent to establish land circulation access system.

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(From page 63)

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